NASA CR 65737

SPACELABS, INC.

QUARTERLY PROGRESS REPORT NO. 3

CONTRACT NO. NAS 9-6649

PROPELLANT LEAKAGE DETECTION SYSTEM

This report covers the period from June 1 to August 31, 1967.

1.0 PROGRAM SCHEDULE

The program is on schedule and is shown in Figure 1.

2.0 GENERAL PROGRESS

During this reporting period, a design review meeting was held at NASA/MSC, Houston, Texas. Persons in attendance were: C. Vaughn and D. Kendrick of NASA/MSC and R. McGann, J. Bisera and B. Gerritsen of Spacelabs, Inc.

A review of the work done by Spacelabs on the PLDS was presented. A clarification of the design specification regarding the maximum pressure drop to be introduced by the flow transducer resulted in a design goal limiting the pressure drop to 1% of the lowest line pressure expected at maximum flow. This would be 1% of 100 psi or 1 psi maximum pressure drop allowable through the flow sensor.

NASA/MSC was questioned relative to sizing of the sensors. The specific contract requirements call for delivery of two prototypes to be integrated with a 1/2" oxidizer and 3/8" fuel line, whereas the system requirements call for line sizes of 3/4" for the oxidizer and 5/8" line size for the fuel, immediately downstream of the storage tanks. It was decided that NASA personnel would review the line sizes desired for the PLDS units.

Electronic packaging was discussed to determine whether the electronic package could be isolated from the transducer, and if it were possible to time-share the electronics with various transducers.

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A possibility exists to isolate all of the electronics from the transducer but is not desirable since any lead length from the thermistor located in the flow stream to the electronics would introduce problems in compensating for environmental changes. A desirable feature would be to place the heater amplifiers as close to the thermistors as possible (enclosed by dotted lines in Figure 2).

No portion of the electronics may be time-shared since the Statement of Work (Exhibit A) under Systems Requirements - RCS Failure Modes to be Detected, requires that detection of small leaks through the thrust chambers be monitored continuously. The high flow leakage warning system is also required to operate continuously. Only that portion below the storage tanks need not be continuously monitored for leakage. To ensure that the response time be minimized, the heater should be left on, which would require that the heater amplifiers not be commutated. A heater amplifier for each transducer is a desirable feature, especially for monitoring small leaks.

The major effort during the quarter was directed to evaluation of various mechanical configurations for flow sensing. A detailed evaluation of the three probe heater sensors indicated that at the very low flow rate (30 cc/hr), the fluid flow seemed to follow a very random pattern, i.e., not a uniform, fully developed, laminar flow.

A flow pattern study was conducted with a glass tube arrangement as shown in Figure 3. It was found that the velocity profile in the tube was not fully developed at the low leakage rates, but appeared as a filament flow. When the injection area temperature was changed the flow profile location would shift as shown in Figure 3. The result of this study coupled with the data obtained through the evaluation of the three probe heater sensor system led to a re-investigation of a single heated body using the constant temperature (variable power) technique to measure flow. A self-heated thermistor inserted in a cylindrical sheath was used as a heater-sensor and two systems were evaluated.

The two systems evaluated were:

(a) Cross-Flow System -- Cylindrical sheath perpendicular to direction of flow (Figure 4a).

(b) Coaxial Flow -- Cylindrical sheath parallel to direction of flow (Figure 4b).

The electronic system for evaluation of both configurations is shown in Figure 5. The results (Figure 6 to Figure 9) show that both the cross-flow and coaxial flow configurations are suitable for flow measurement.

To determine the optimum mechanical configuration for low flow measurement, the results of four basic systems were evaluated for sensitivity to flow rate, orientation, power requirement and electronic arrangement.

The systems evaluated were:

(a) Cross-Flow System (Figure 4a)

(b) Coaxial Flow System (Figure 4b).

(c) Folded Flow Path System (Figure 10).

(d) Three Probe Heater Sensor (Figure 13).

The output voltage change to flow rate is shown in Figures 6, 8, 11 and 15. The results indicate that the cross-flow system and the three probe heater sensor system to be most sensitive to flow. A 540 millivolt change corresponding to flow rate changes from 0 cc/hr to 600 cc/hr was observed for the cross-flow system and a 480 millivolt change in the three probe heater sensor system for an equivalent flow rate change.

An indicated flow rate versus orientation with the actual flow rate being a parameter is plotted in Figures 7, 9, 12 and 16. A composite plot for the orientation effects is shown in Figure 17 with the actual flow rate being 0 cc/hr. The results indicate the cross-flow system to be the least sensitive to orientation change of $0° \pm 90°$ with a maximum indicated flow rate of 15 cc/hr at an actual flow rate of 0 cc/hr.

A comparison of the electronics necessary (Figures 5, 10 and 14) to measure flow indicate the cross-flow and the coaxial systems require less components and are simpler to fabricate. The reduced number of components results in a lower power requirement for both systems as shown in the bar graph (Figure 18).

The result of the evaluation of the four basic systems led to the decision of using the cross-flow system to measure low flow rates.

The results of an initial attempt to temperature compensate the experimental cross-flow system using water as fluid is shown in Figure 20 with the test setup shown in Figure 19. A schematic of the compensation network is shown in Figure 21. The system was compensated at a 0 cc/hr flow rate ($h_f = 0$). The results indicate a larger deviation at the low temperature (4°C) than at the higher temperature (41°C) from a nominal of 20°C. A close examination of Figures 22 and 23 indicate that for water, the change in the forced convection coefficient (h_f) at 4°C is much greater than at 41°C. The large deviation may be attributed to the system being compensated at no flow rather than at some fixed flow rate.

Since all fluids exhibit different characteristics with temperature, it is necessary to compensate the flow sensor system with the actual fluid being used. Expected operating conditions should then be simulated as much as possible. The compensation network for one configuration will not necessarily be the same for each system even though the same fluids are used. Hence, all configurations must be compensated individually.

Investigation for a test facility using the actual fuels has been initiated. A bid was received from Wiley Laboratories in the Los Angeles area. A second alternative, use of a NASA facility operated by Rocketdyne, is being investigated by NASA. It is not anticipated that the propellant tests can be conducted at the present Spacelabs facility without extensive modification.

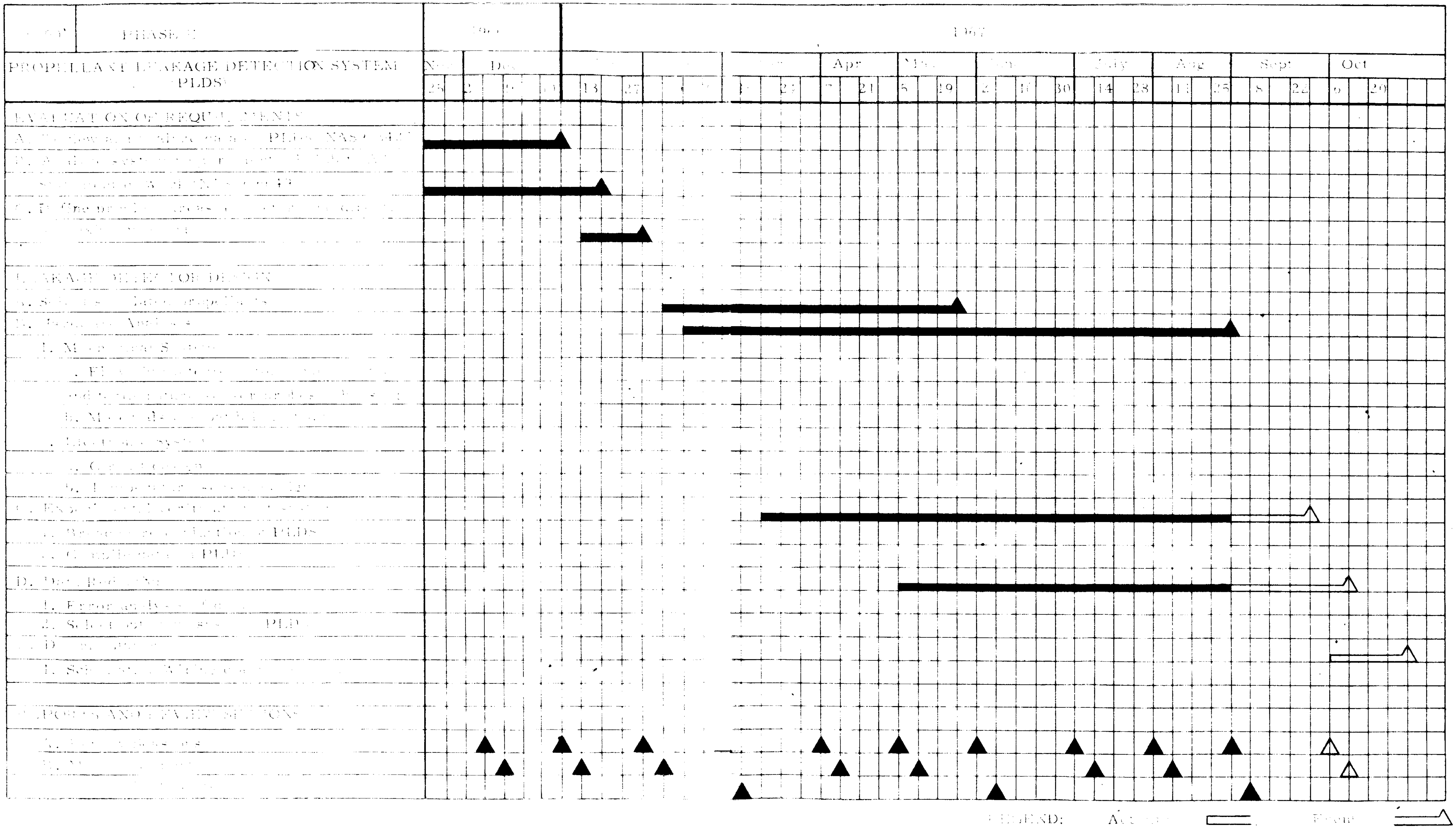
3.0 WORK TO BE PERFORMED DURING THE NEXT REPORTING PERIOD

(a) Design one (1) dual type cross-flow sensor.

(b) Evaluate one (1) prototype cross-flow sensor utilizing a venturi.

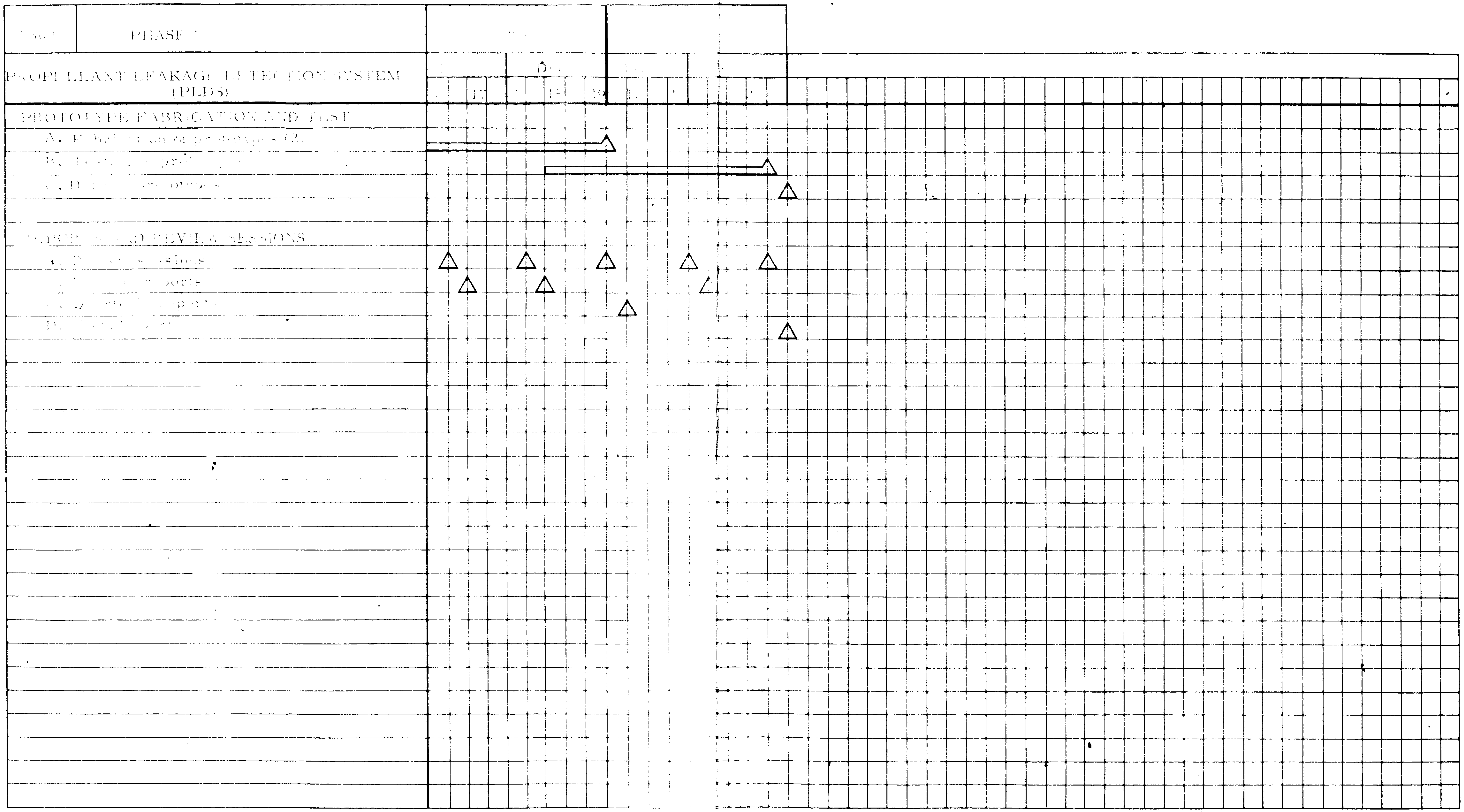
(c) Continue evaluation of temperature compensation techniques using experimental cross-flow model.

SPACELABS, INC. PROGRAM SCHEDULE



FIGURE

SPACELABS, INC. PROGRAM SCHEDULE



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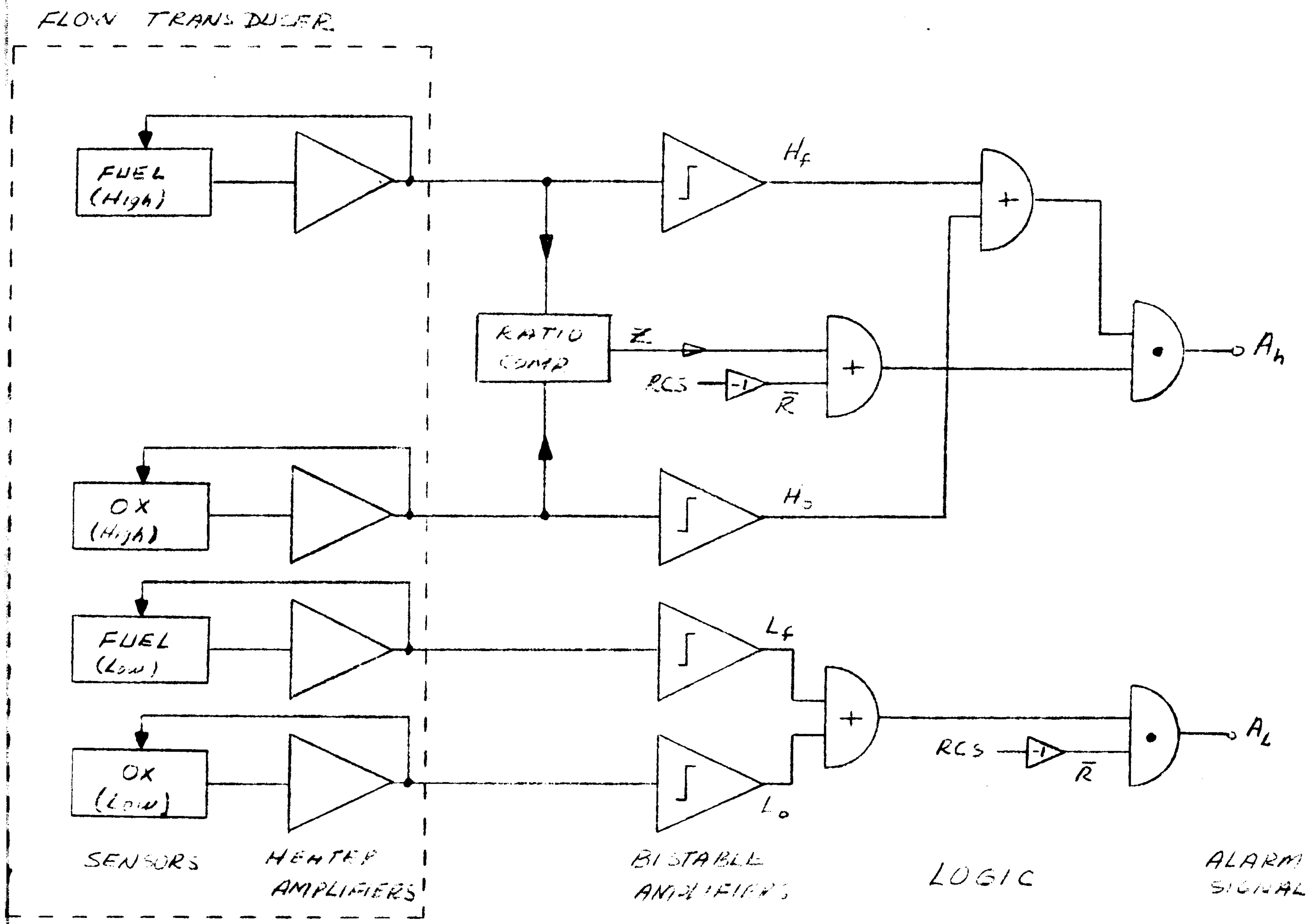
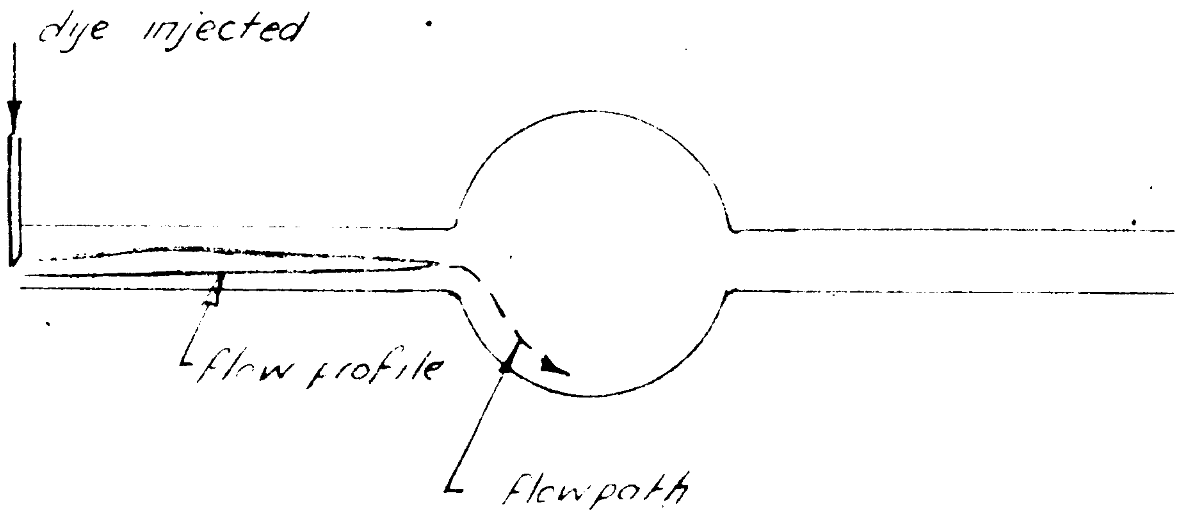
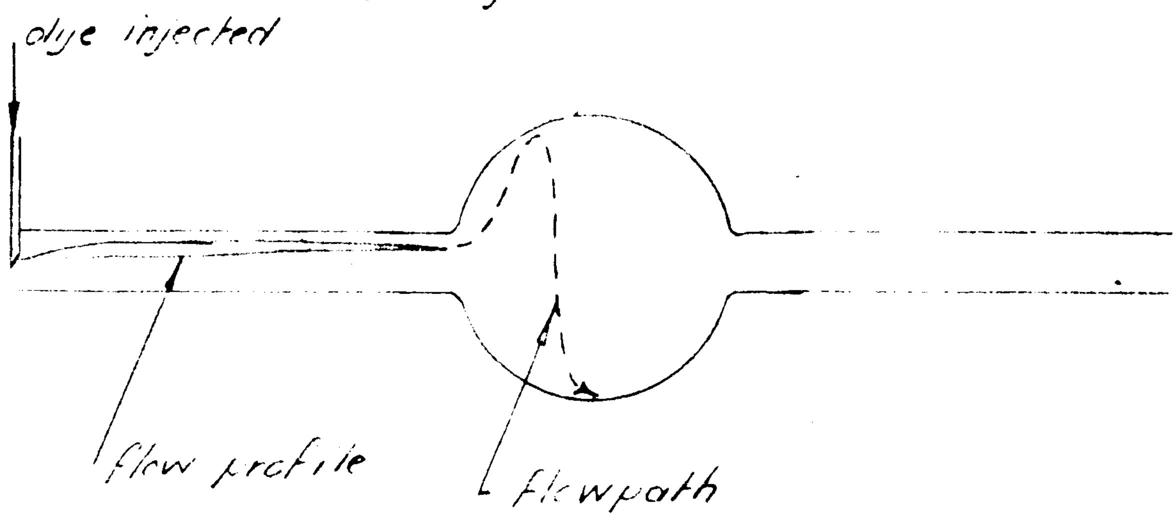


Fig 2 Block Diagram - PLDS



CASE 1 : Injection area cooled



CASE 2 : Injection area heated

FIG. 3

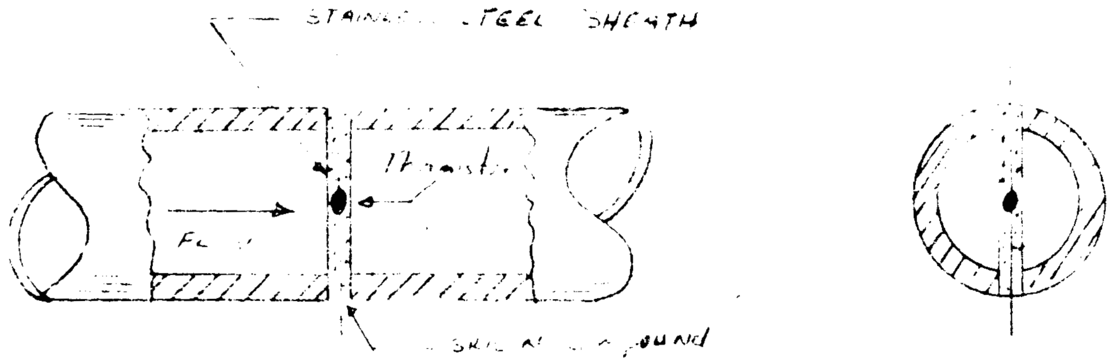


Fig 4a CROSS-FLOW SYSTEM

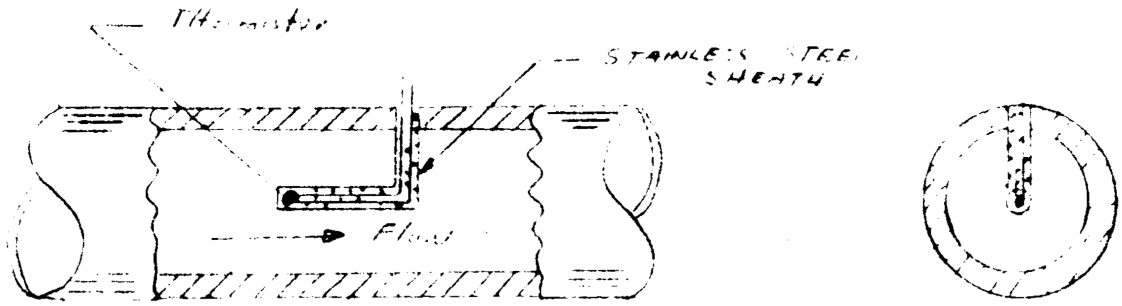
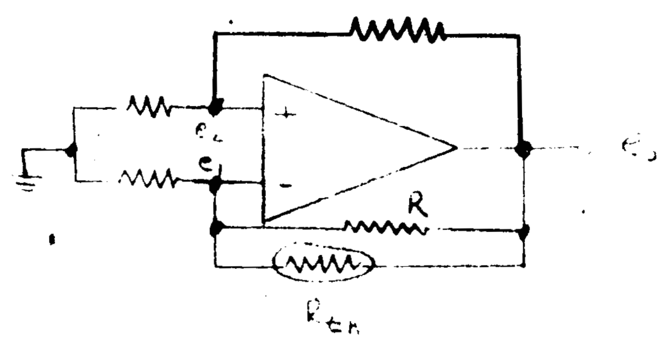


Fig 4b COAXIAL FLOW SYSTEM



R_{th} - Self heated thermistor

Fig. 5 Schematic of Self-heated sensor electronic system

CROSS - FLOW SYSTEM

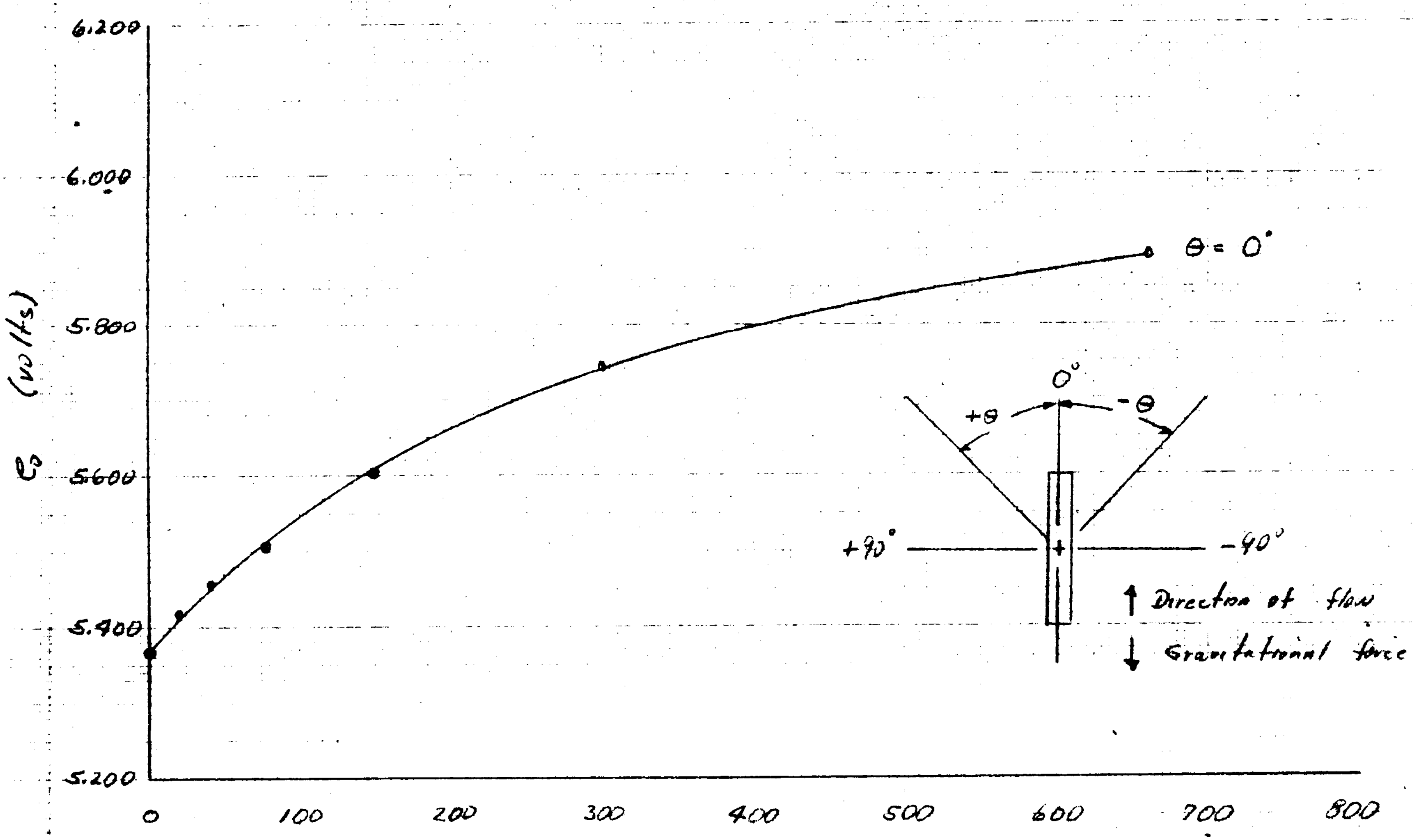


Fig 6 Flow rate (cc/hr)

CROSS-FLOW SYSTEM

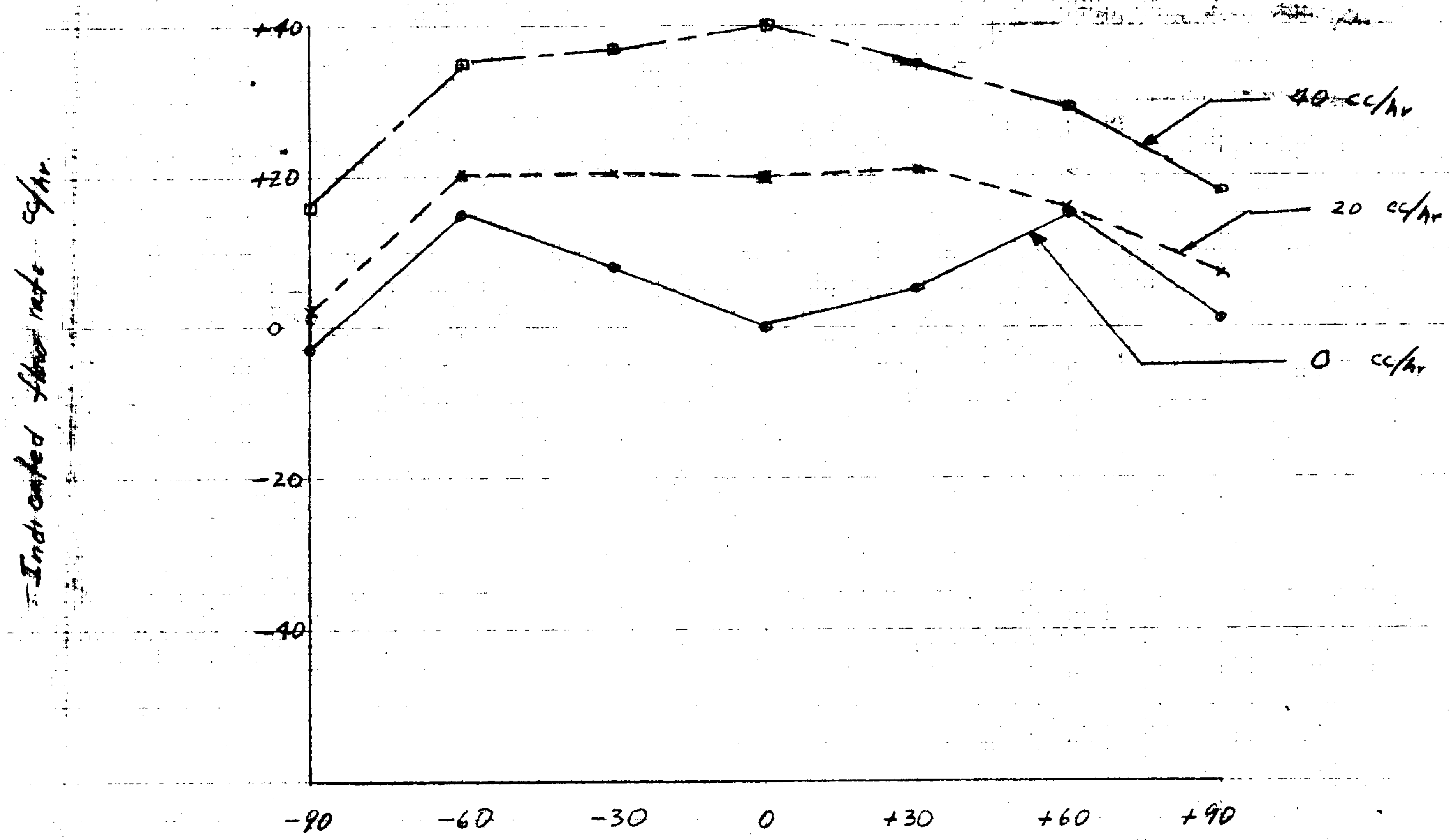


Fig 7 Tilt angle "θ" degrees

COAXIAL-FLOW SYSTEM

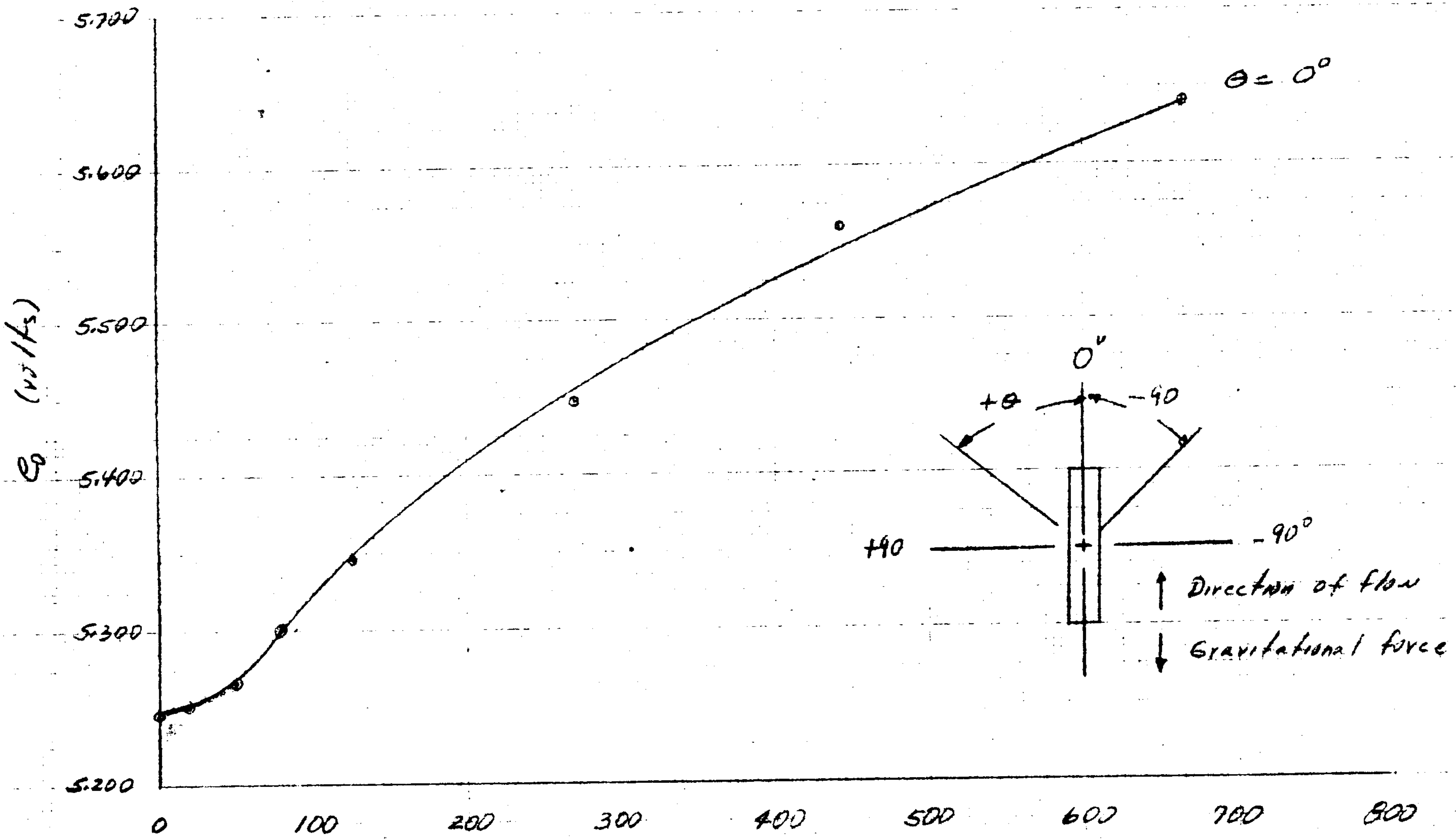


Fig. 8 Flow Rate cc/hr

COAXIAL FLOW SYSTEM

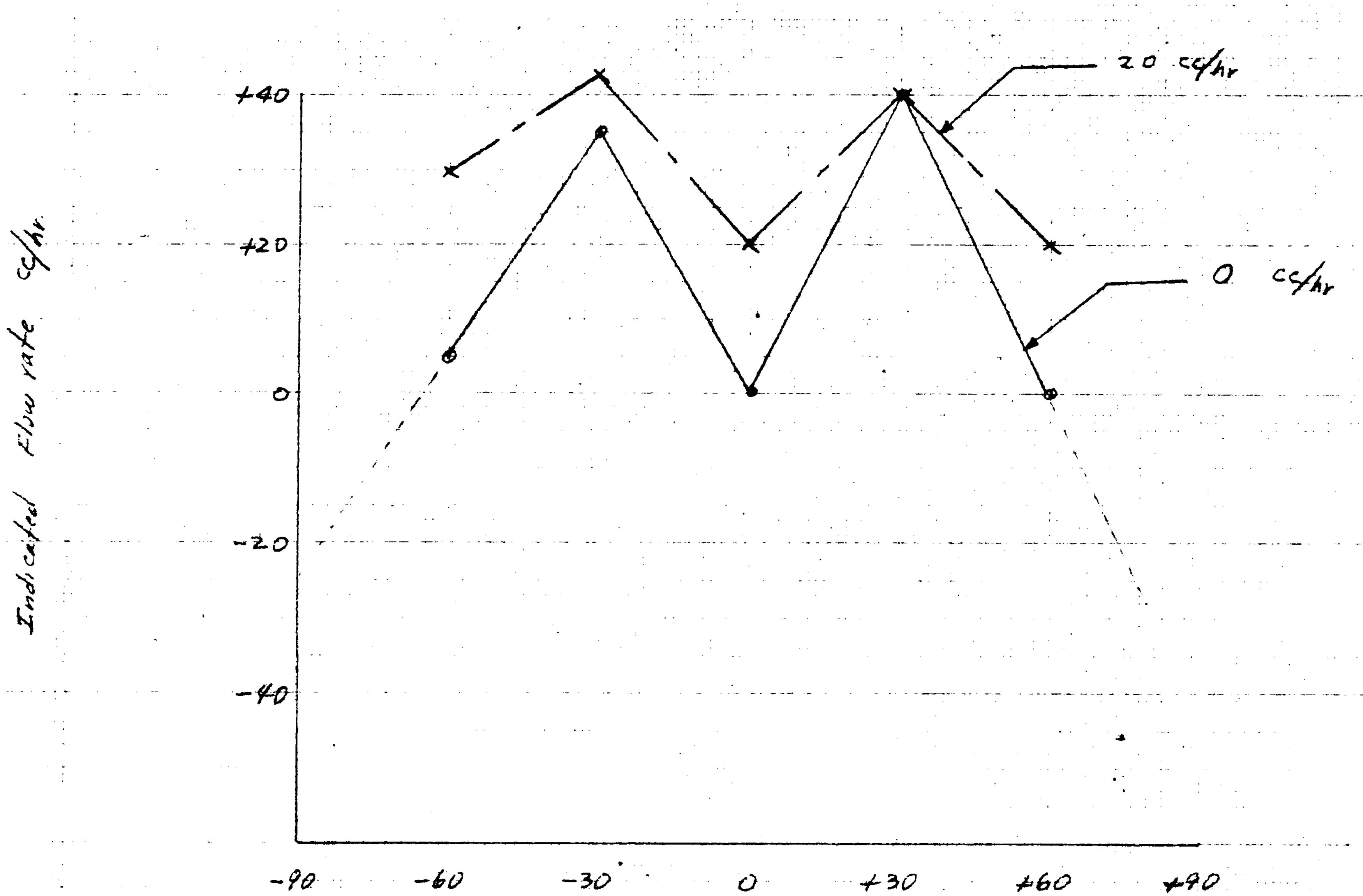
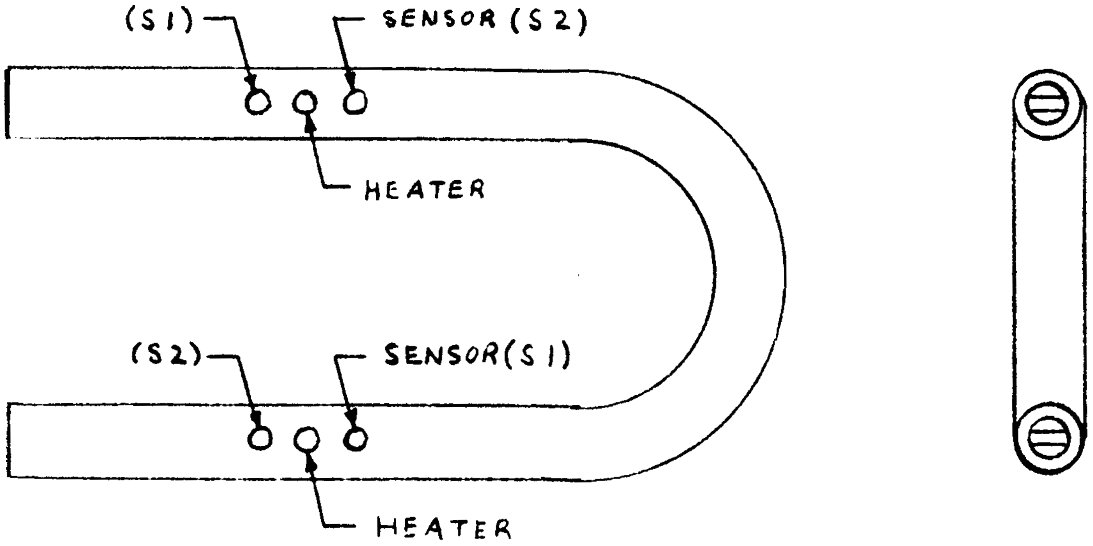


Fig 9 Tilt angle "θ" degrees



FOLDED FLOW PATH

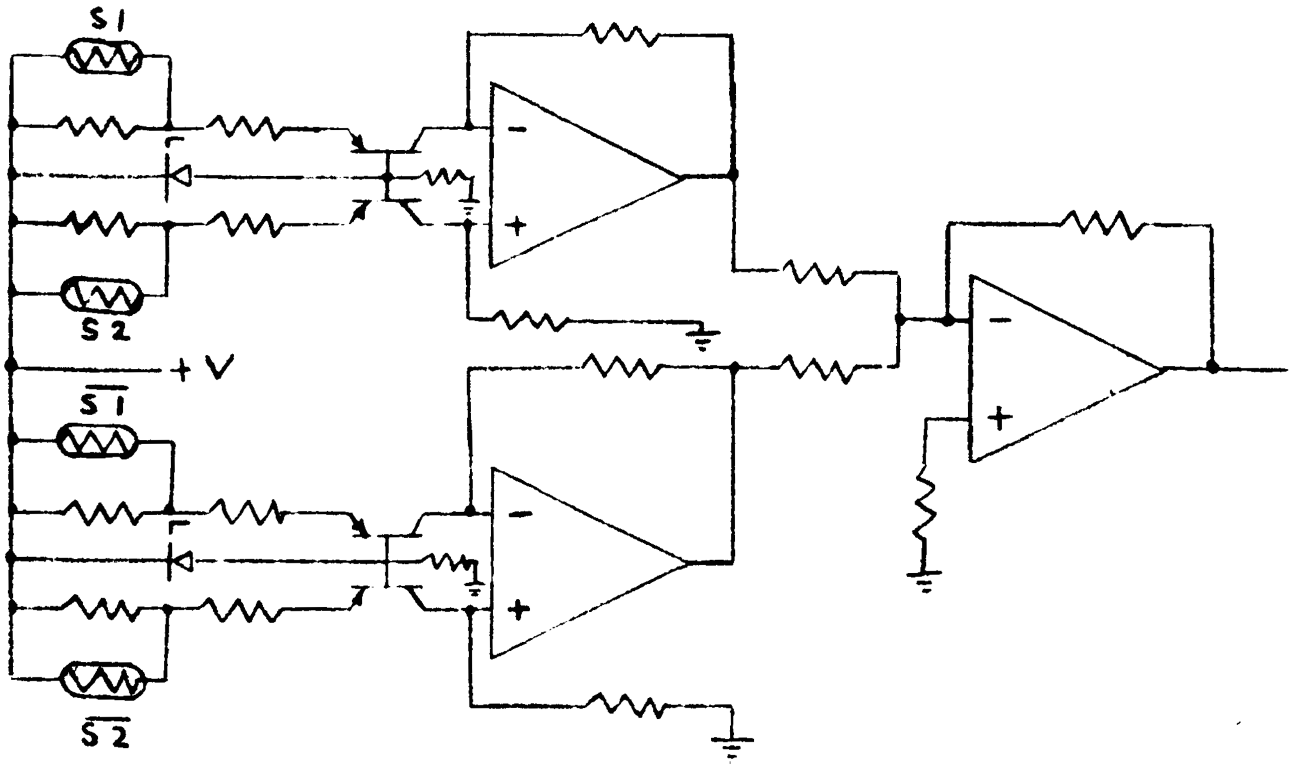


FIG 10 SCHEMATIC: FOLDED FLOW PATH SYSTEM

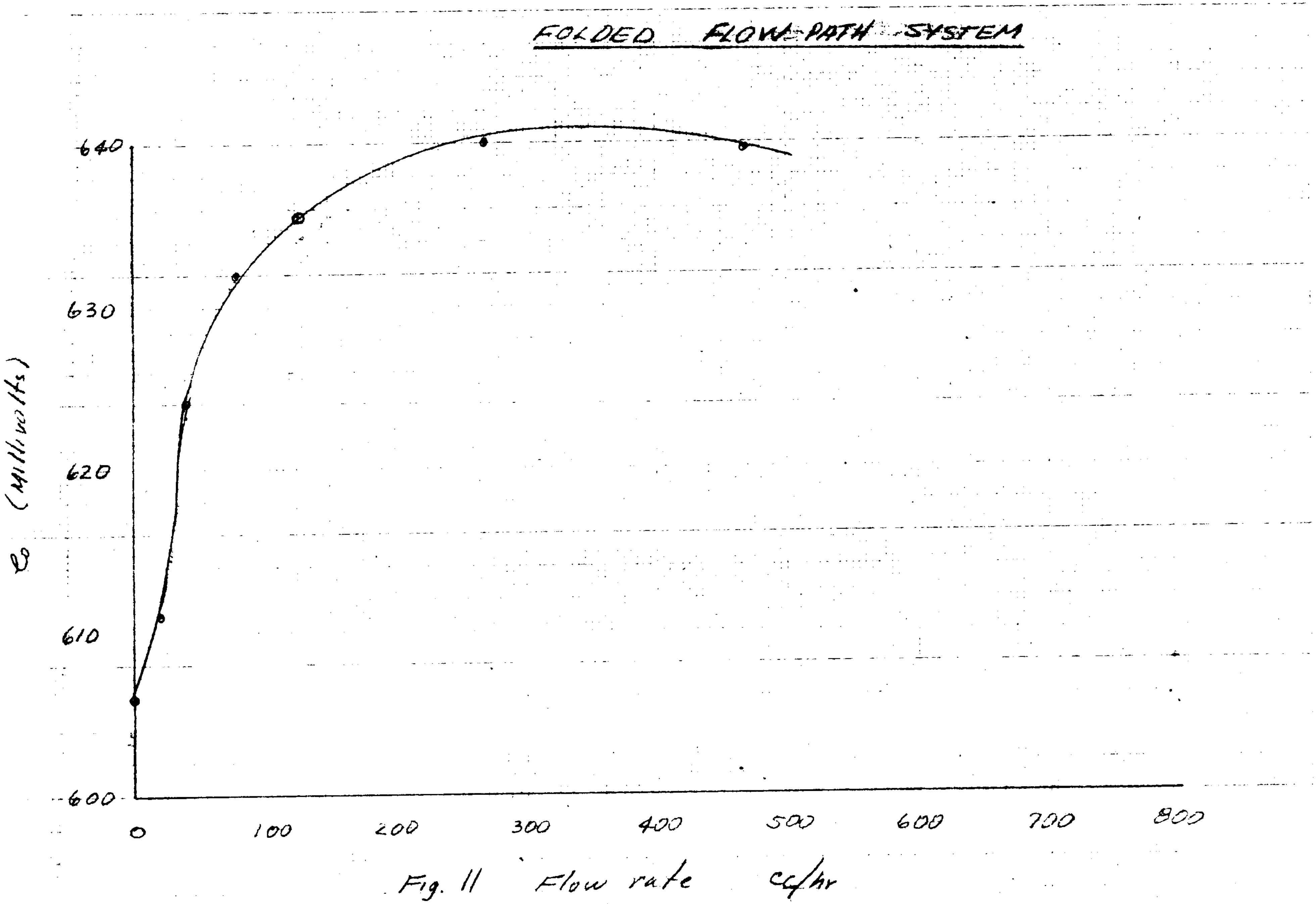

FOLDED FLOW-PATH SYSTEM
640
630
620
610
600
e (Millivolts)
0
100
200
300
400
500
600
700
800
Flow rate cc/hr

Fig. 11

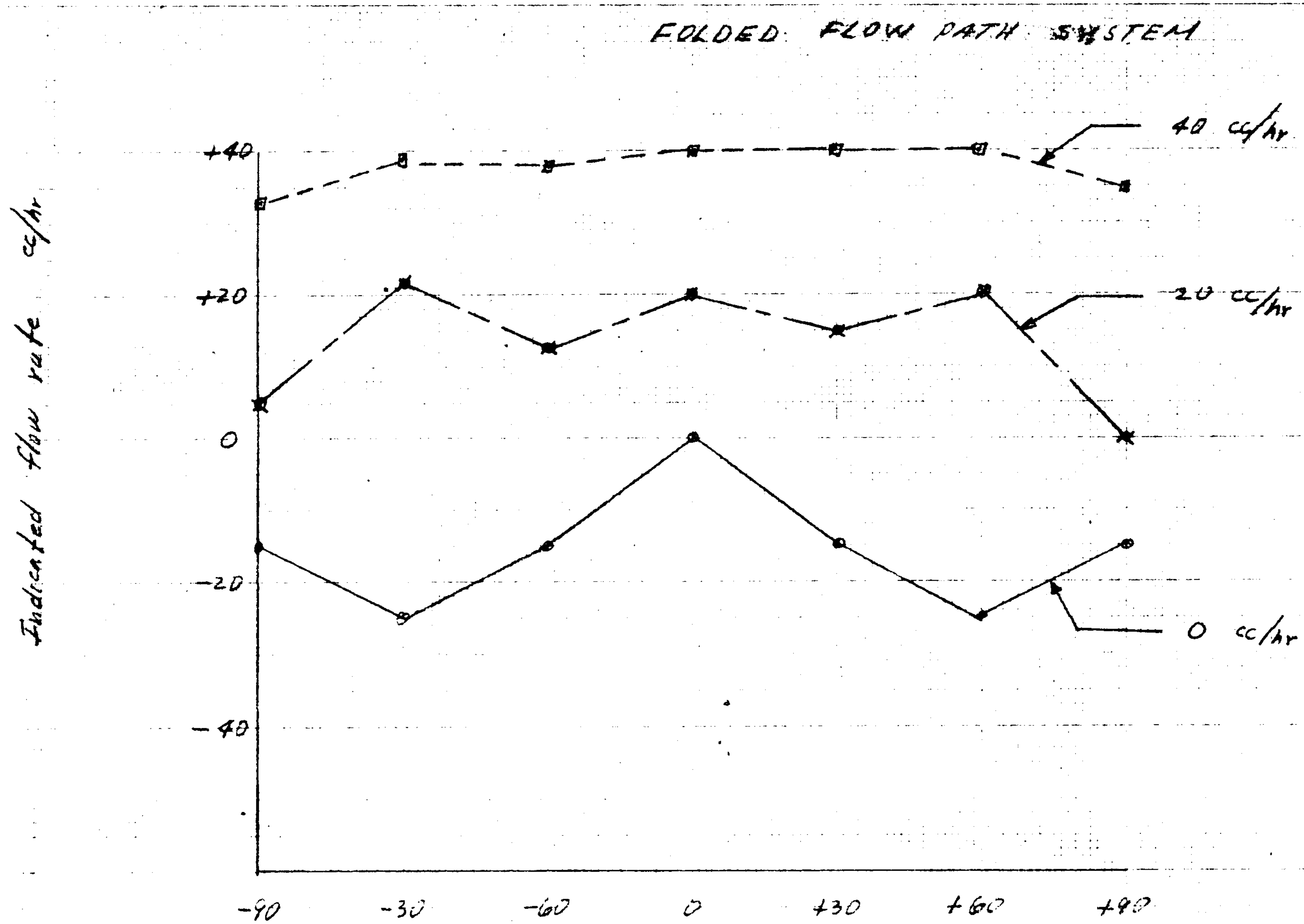


Fig. 12 Tilt angle "θ" degrees

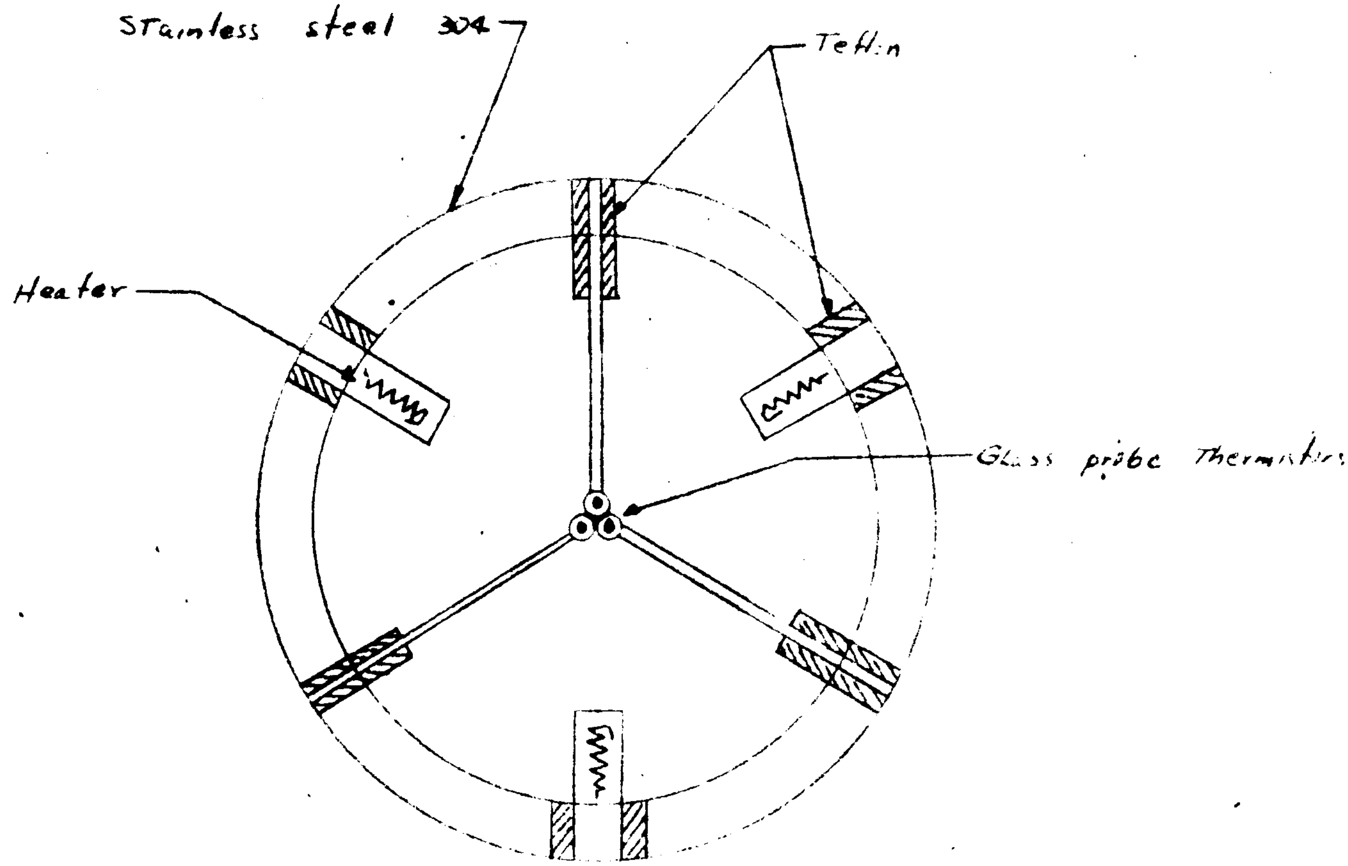
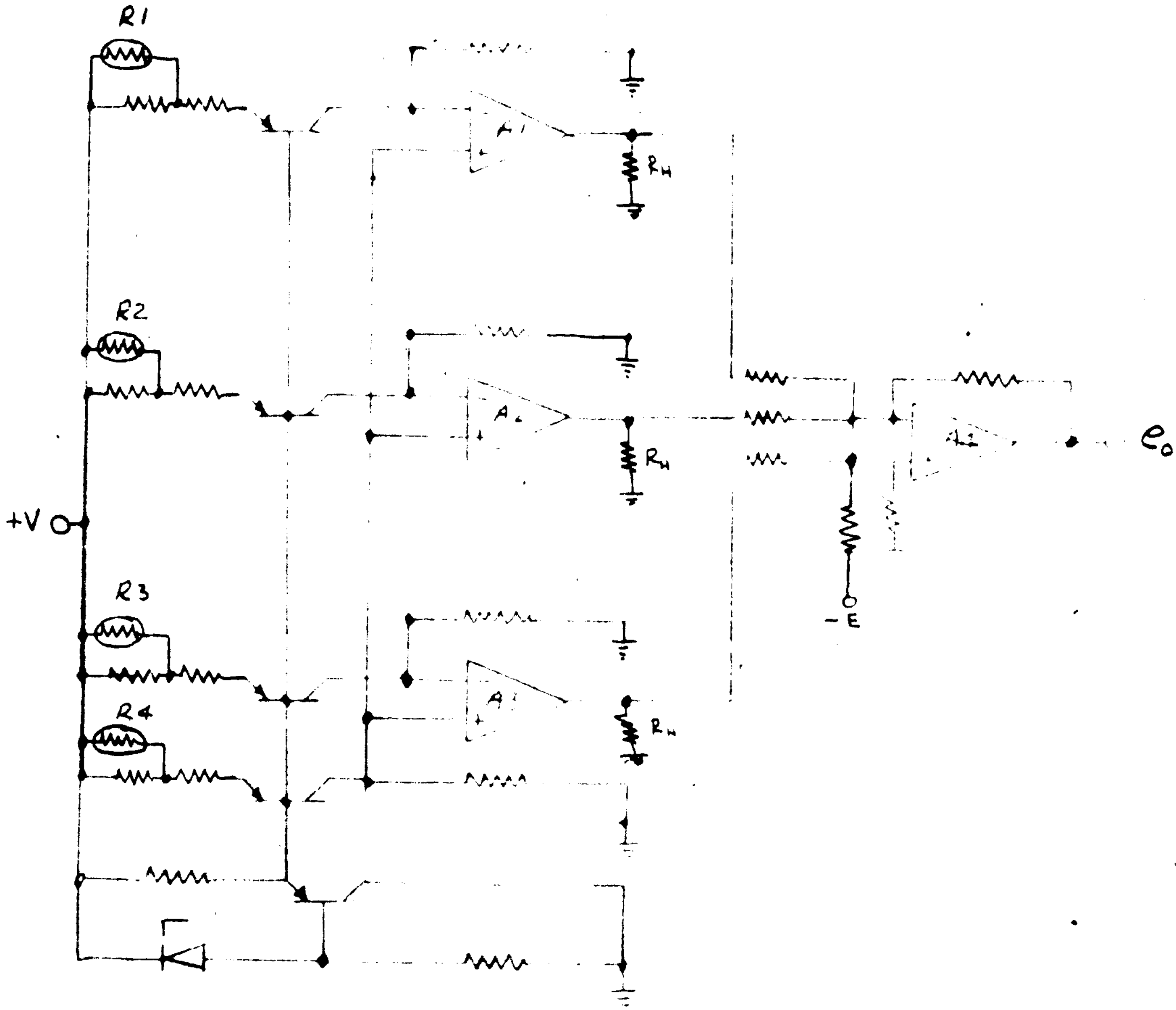


Fig. 13 Three "Temperature sensor" System
(Thermal Differential System)



R1 to R4 are thermistors
R_H are heater Resistors

Fig 14 Schematic: Constant temperature differential System (Three probe)

Three probe flow system

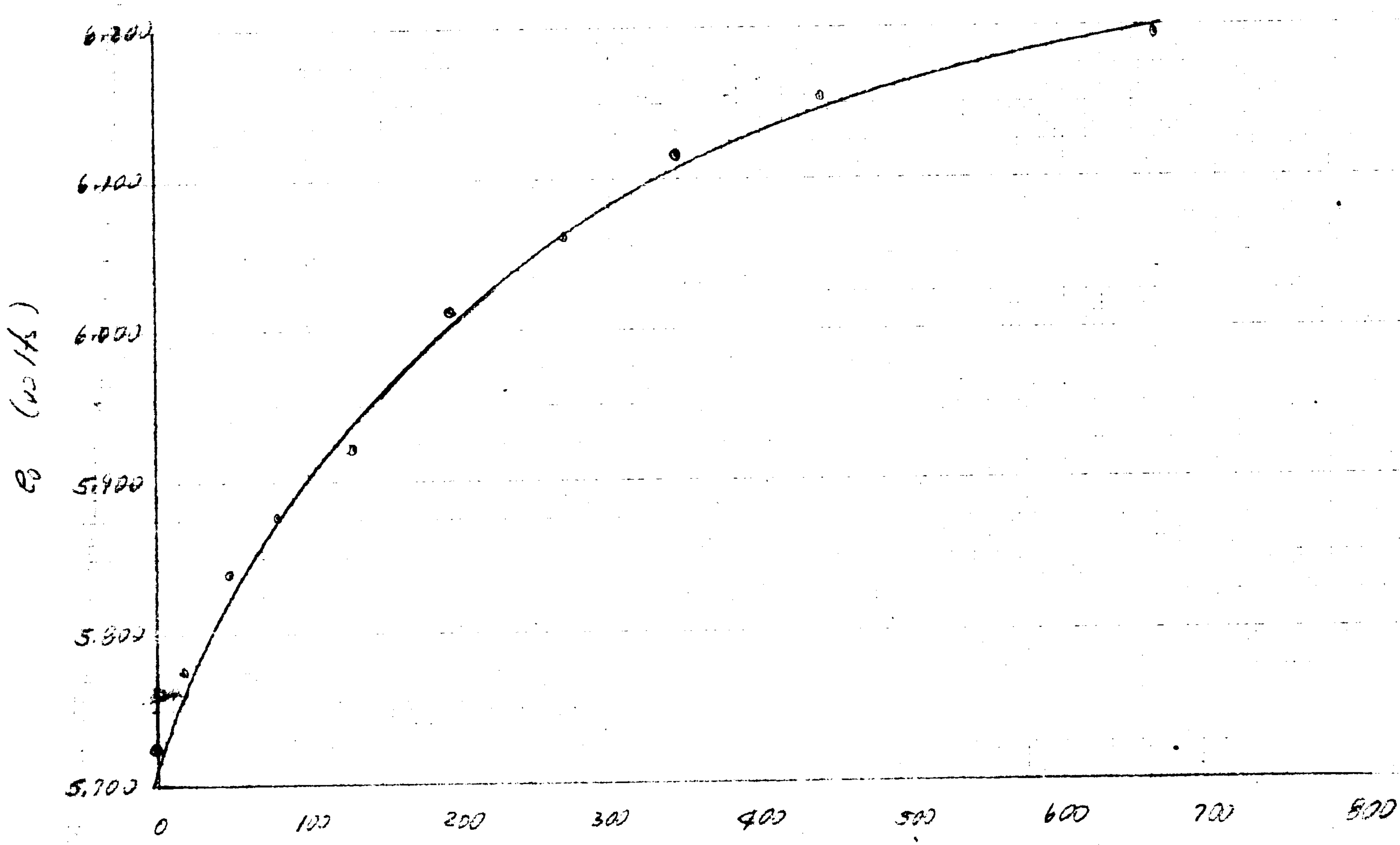


Fig 15 Flow rate

THREE PROBE FLOW SYSTEM

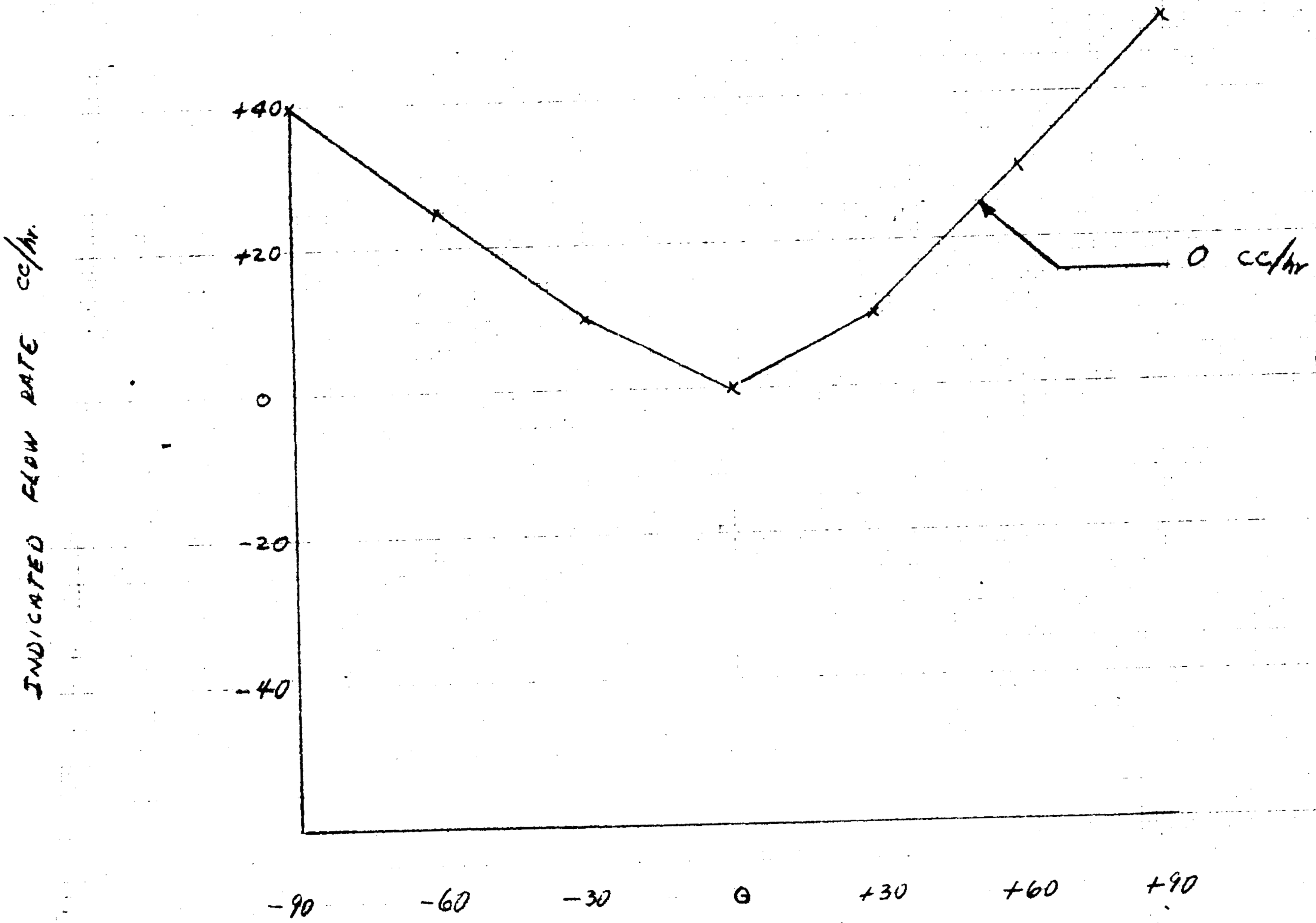


Fig 16 Tilt [illegible] "θ" [illegible]

COMPARISON OF CONFIGURATIONS

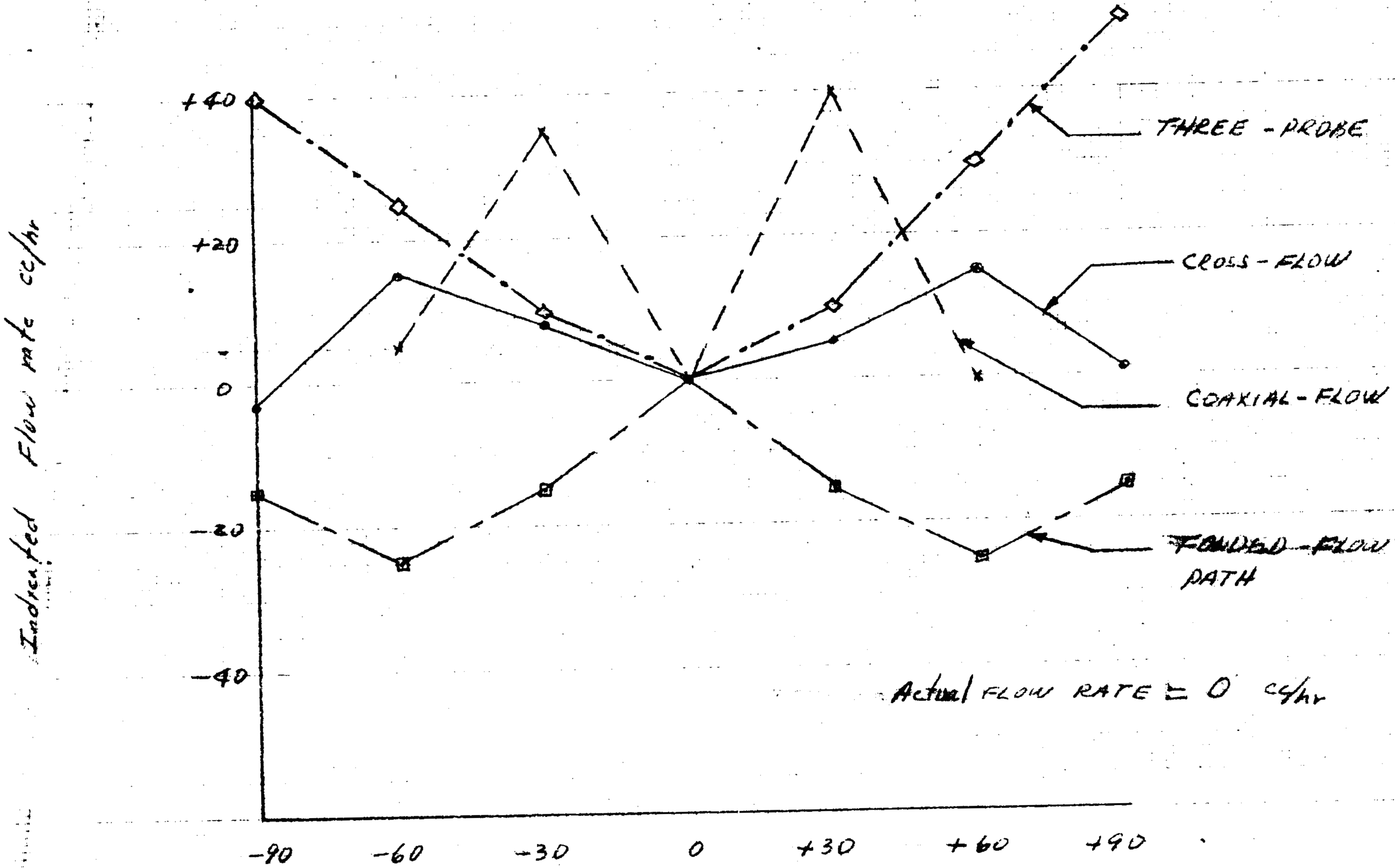


Fig. 17 Tilt angle "θ" degrees

POWER REQUIREMENT

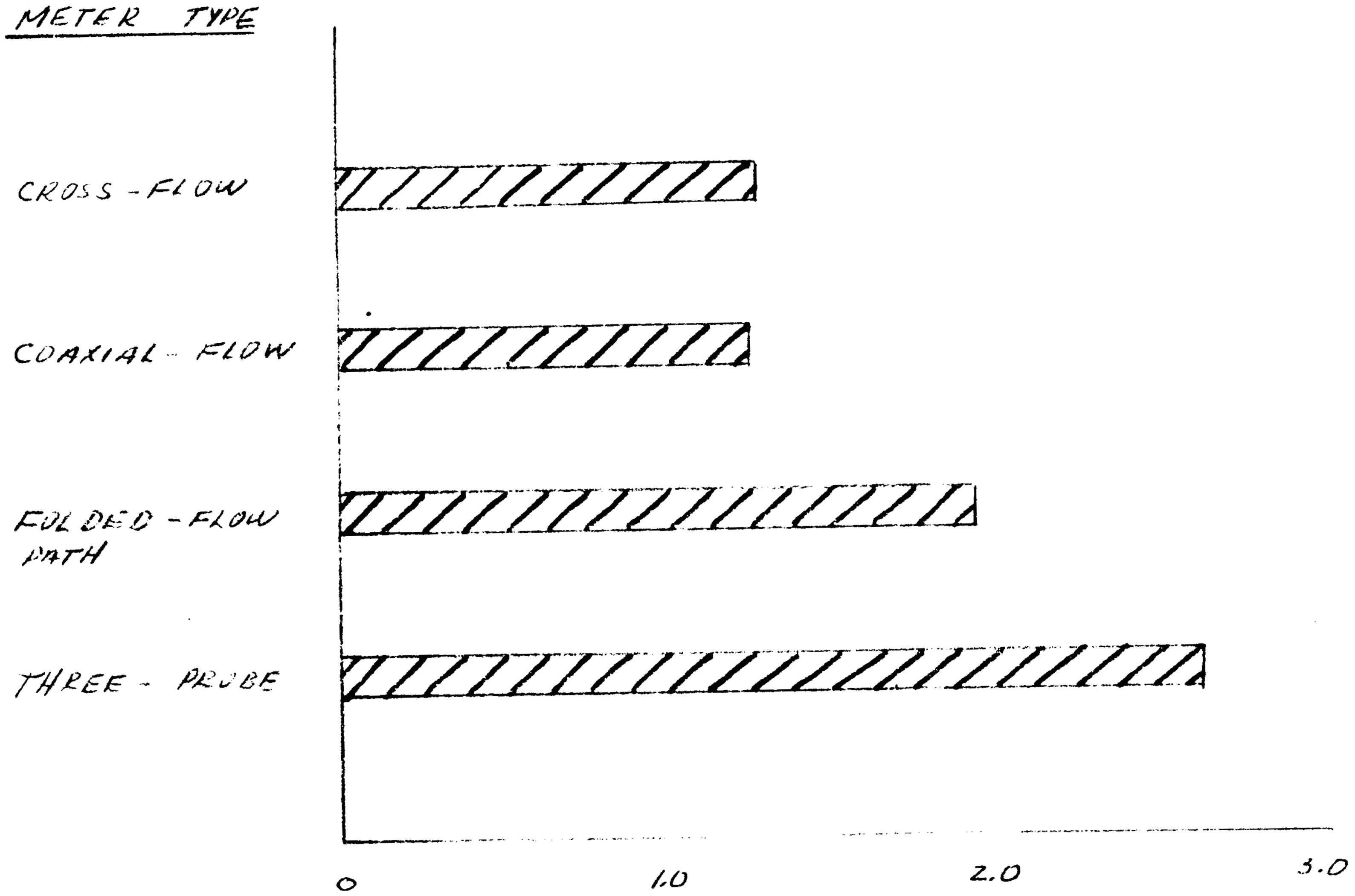


Fig. 18 REQUIRED POWER PER DUAL SENSOR
(WATTS)

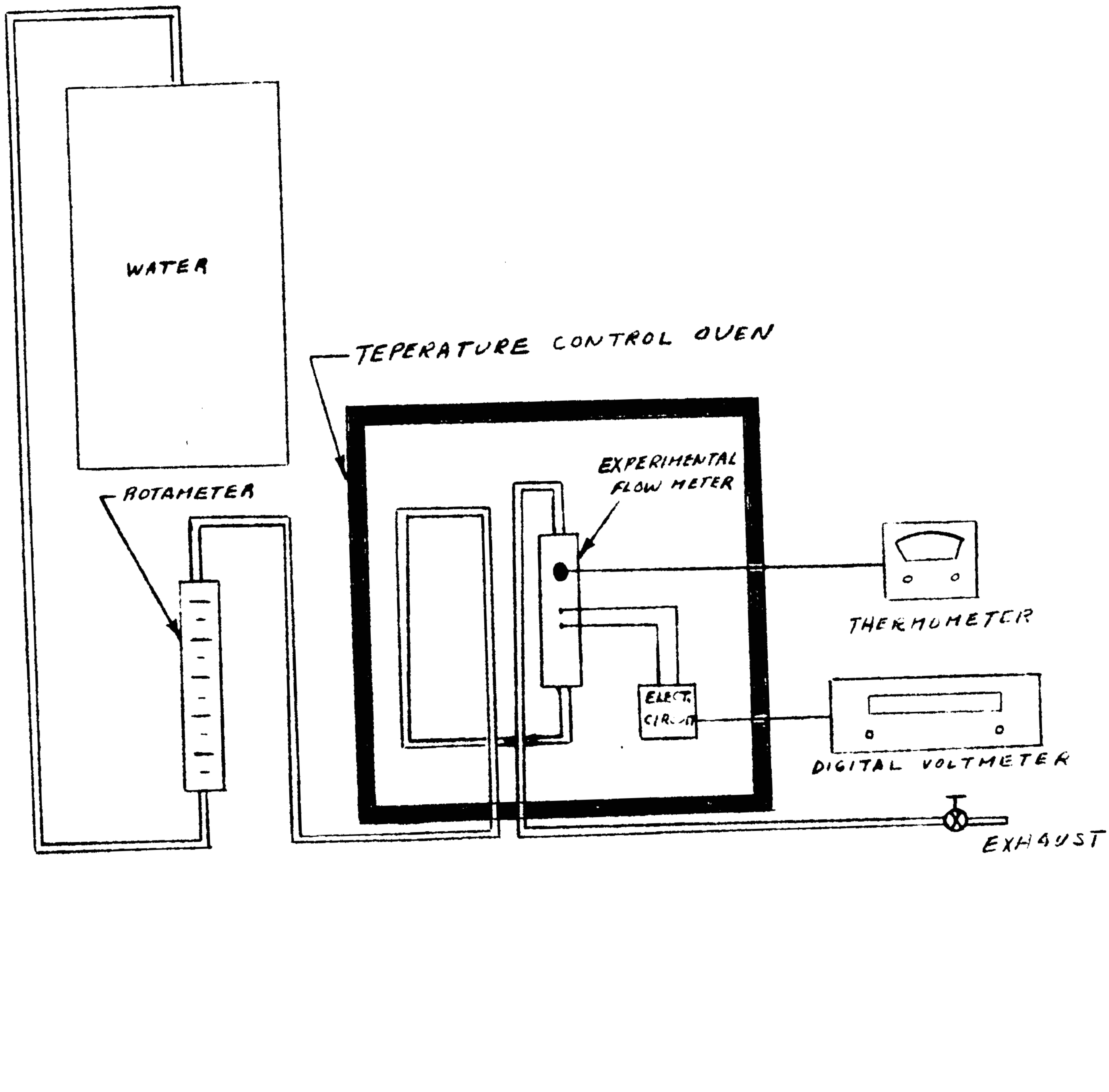


FIG 19 FLOW METER TEMPERATURE TEST SET-UP

CROSS FLOW SYSTEM

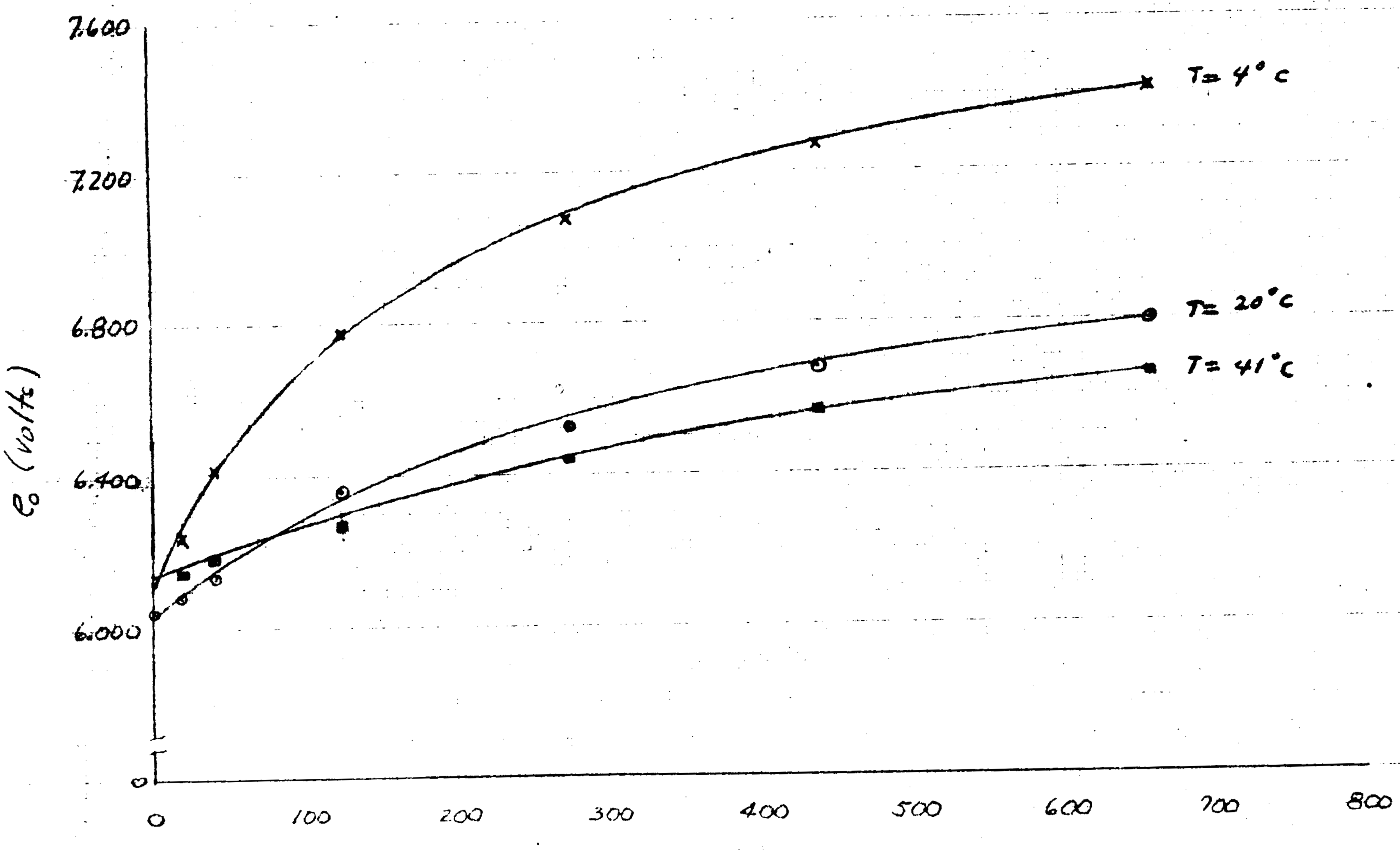


FIG 20

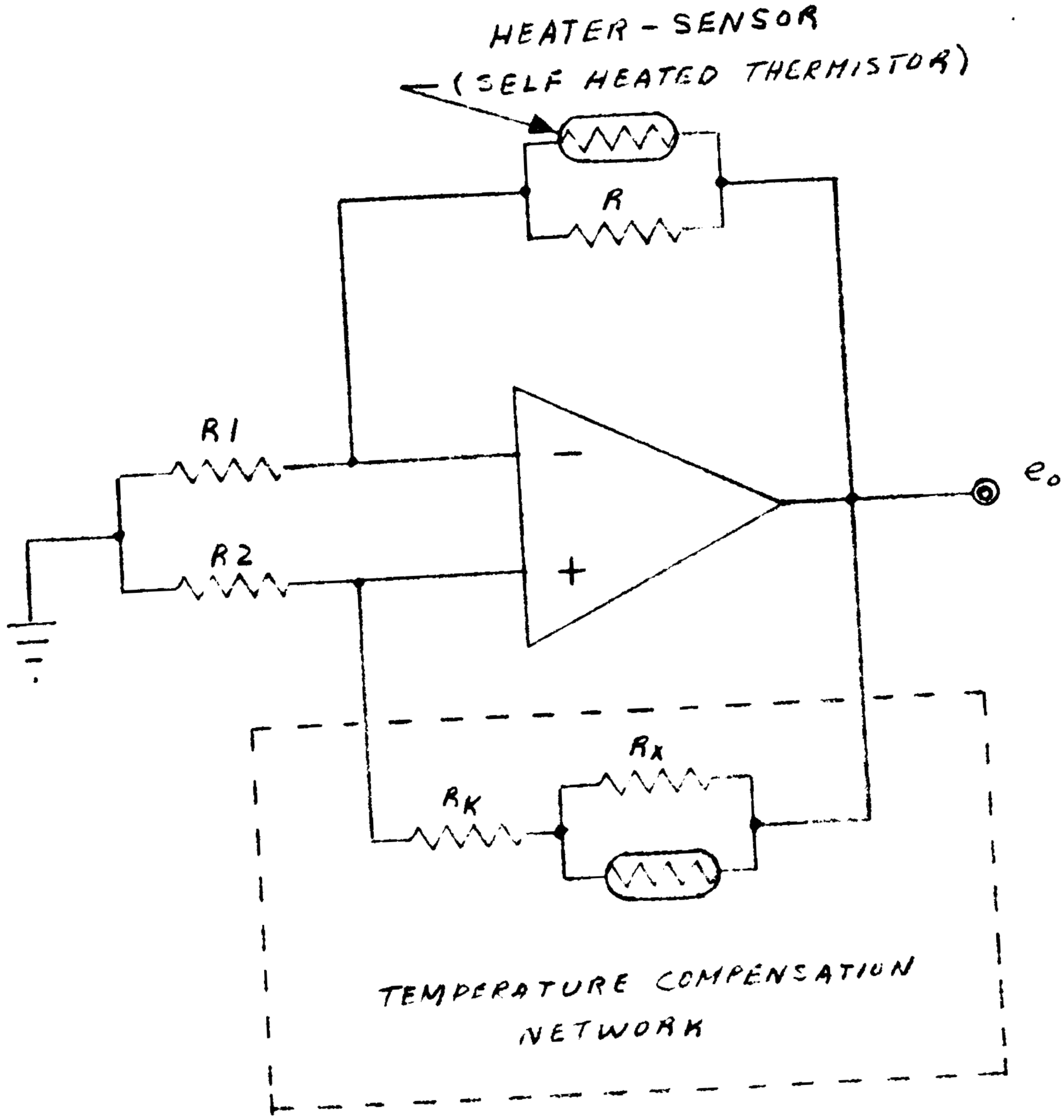
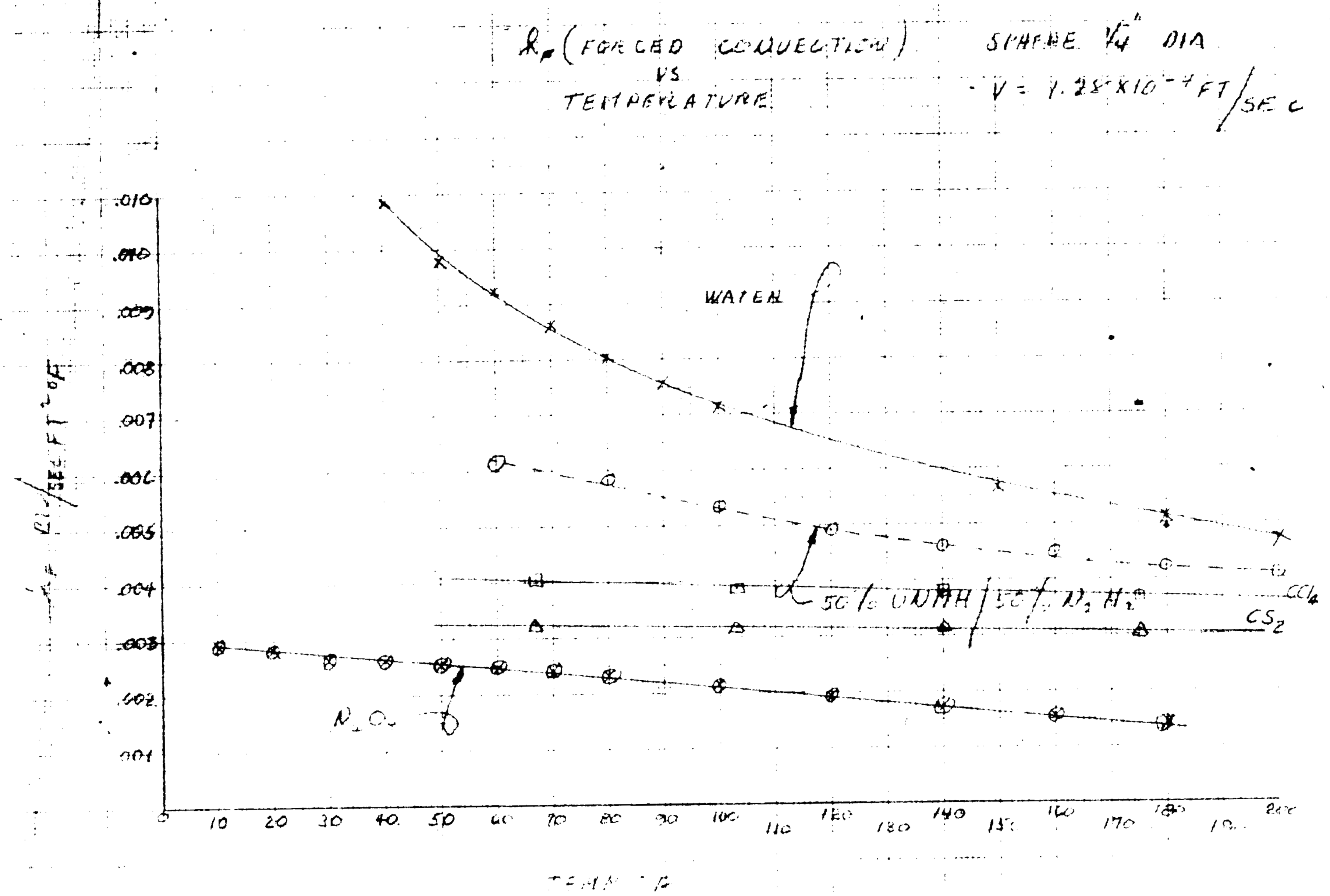


FIG 21 SCHEMATIC - HEATER AMPLIFIER WITH COMPENSATION



k_f (FORCED CONVECTION) VS TEMPERATURE
SPHERE 1/4" DIA
V = 1.28 X 10⁻⁴ FT/SEC
WATER
50% UDMH / 50% N_2H_4
CCl_4
CS_2
N_2O_4
.010
.009
.008
.007
.006
.005
.004
.003
.002
.001
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

Fig 22

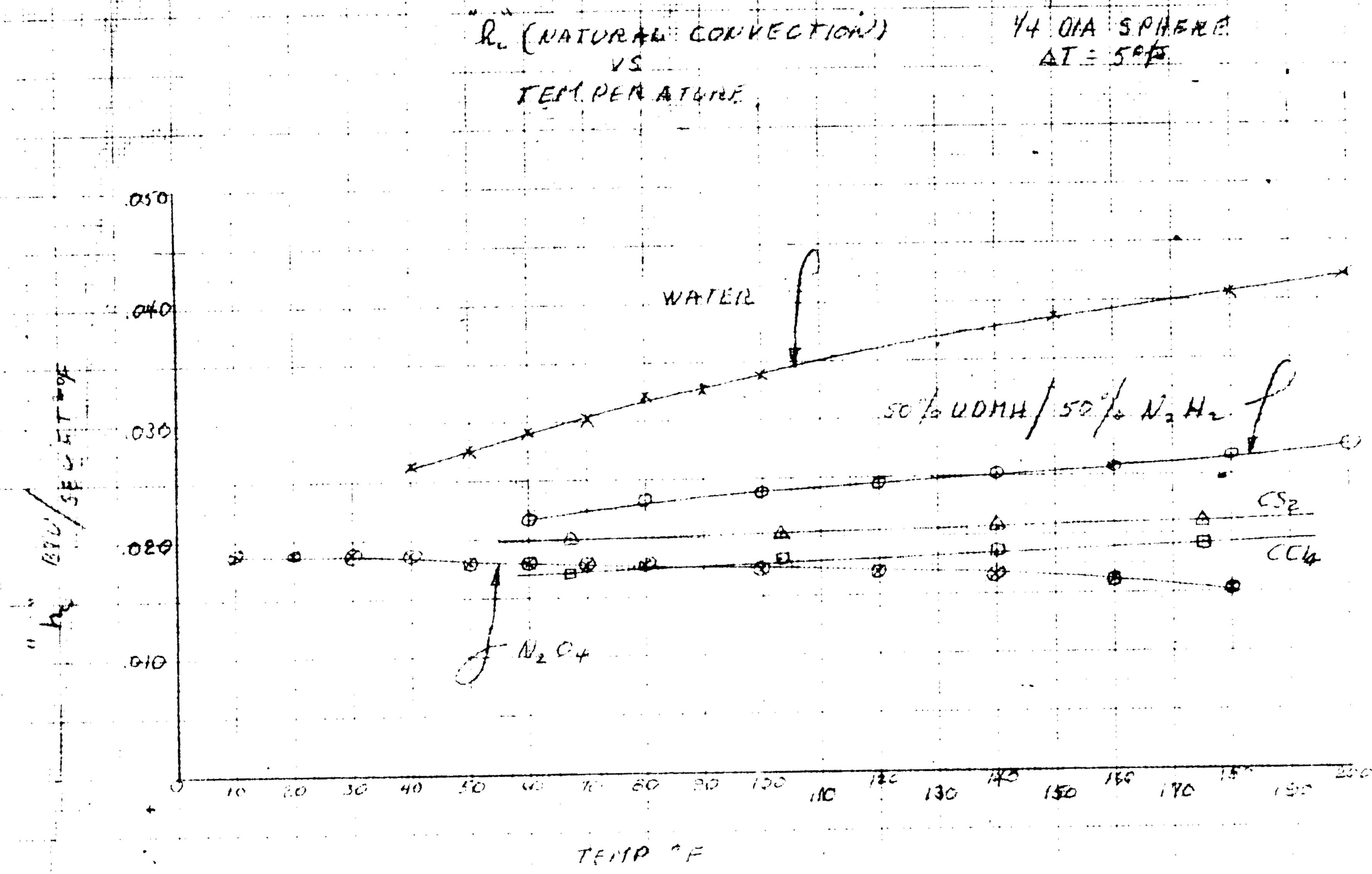

"h_c" (NATURAL CONVECTION)
VS
TEMPERATURE
1/4 DIA SPHERE
ΔT = 5°F
WATER
50% UDMH / 50% N_2H_4
CS_2
CCl_4
N_2O_4
"h_c" BTU/SEC FT² °F
.050
.040
.030
.020
.010
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
TEMP °F

Fig 23